International Journal of Applied Engineering
Research and Development (IJAERD)
ISSN(P): 2250-1584 ISSN(E): 2278-9383
Vol. 4, Issue 5, Oct 2014, 19-32

OPERATION AND PERFORMANCE TESTING OF THE HAZARDOUS (BIOMEDICAL) WASTE INCINERATION PLANT FOR HOSPITALS

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ABSTRACT

The objectives of the present research are to implement the operating and performance testing of the hazardous waste incineration plants. The optimal design of these incineration plants are inline twin combustion chamber, fixed hearth, pyrolytic and controlled air (starved-air) incinerators, supplied with wet air pollution control systems (APCS), which are the most accepted safe, suitable and proper disposal method for hazard (biomedical) wastes. Many of our hazard wastes incineration plants have a capacity of 50, 100, and 250kg/h, were installed for real operating condition in general hospitals of Egyptian Ministry of Health & Population. Numerous runs were done for operating and performance testing on these incineration plants by the approved environmental laboratories of "Reference laboratory of Faculty of Science, Ain Shams University", and "Laboratories of Environmental Measurements" of branches of the "Egyptian Environmental Affairs Agency" (EEAA).

The results obtained from operating and performance testing of these incineration plants can be summarized as range values follow : The average temperature of primary combustion chamber was varied between 810-840ºC, the temperature of secondary combustion chambers was varied between 1100-1140ºC, temperature of gaseous emission from the chimney was varied between 110-130ºC, and the temperature of the outer surfaces of the incinerator bodies was varied between 37-46ºC, while, the ambient temperature was varies between 25-32ºC. Residual ash was varied between 4-5%, corresponding to destruction rate varied between 95-96%. Particulate matter: 6.9-9.05mg/m^3, organic carbon: 1.4-7.4mg/m^3, HCl: 5.6- 8.3mg/m^3, HF: 0.2-0.6mg/m^3, CO: 28-92.5mg/m^3, SO2: 7.9-25.06mg/m^3, NOx: 45.5-88.1mg/m^3. Moreover, the testing is also conducted to measure the heavy metals. Therefore, the emission of pollutants emitted from these incineration plants is found to be lower than the emission standard level issued from (EEAA). So, this incineration plants are complied with the specification and rules of "Egyptian Environmental Affairs Agency (EEAA)".

KEYWORDS: Incineration Plant, Operating Parameters, Gaseous Emission

INTRODUCTION

Incineration is the process by which combustible materials are burned, producing combustion gases and non-combustible residue and ash. Another major objective of the incineration process is the destructive of infectious organisms (pathogens) that may exist in the waste. Two additional objectives achievable through proper operation of hospital waste incineration plants are waste reduction and controlling atmospheric emissions to acceptable levels. Hazardous waste incineration plants for hospitals are potentially significant sources of air pollutants. Pollutants include particulate matter; toxic organics; carbon monoxide; acid gases; hydrogen chloride; sulphur dioxide and nitrous oxides. The primary objectives associated with the proper operation of hospital waste incineration system are to operate the system in a manner

so that infectious materials in the waste are rendered harmless, waste volume reduced, good ash quality (from an aesthetic standpoint) is ensured, and air pollution emissions are minimized to a level less than the standard levels [1].

Samwel V. Manyele, et al. [2] made a study which was aimed to assess the performance of the combustion process during medical waste incineration by studying physical properties of the ashes produced. Combustion characteristics data including maximum temperatures, total weight of waste loaded, weight of ashes, weight reduction, sieve analysis and particle size distribution were determined experimentally. Their test runs were conducted in a newly installed incinerator at Temeke district hospital, Dar es Salaam, Tanzania. The average maximum temperatures achieved in the primary chamber was 397.8°C and 839°C for secondary chamber with average incineration cycle time of 99 minutes. These temperatures were lower compared to the design temperatures of 650°C and 950°C as a result of loading wet waste. The ash samples were collected under the incinerator grate by randomly sampling the ashes for each run after weighing the total ash. The particle size distribution of ashes observed was not uniform due to presence of non-combustible materials in the sharps waste. However, the fineness modulus ranged between 2.0 and 4.0, which is in the acceptable range. From their above results it was concluded that, the incinerator performance was high in terms of the parameters assessed.

A research interested with burning experiment study of an integral medical waste incinerator was made by Rong Xie, et al. [3]. They found that mass burning of the medical waste is becoming attractive in China because Chinese government has banned land filling of medical waste. Also, many advantages can be found in this method, such as reduction in waste volume, destruction of pathogens and transformation of waste into the form of ash. In their paper, a novel integral incinerator is developed with combining a feeder, grate, a primary combustion chamber (PCC) and a “coaxial” secondary combustion chamber (SCC) into a unique unit.

Their results showed that the temperature of the PCC varied significantly with time because of the intermittent feed and the heterogeneous characteristics of the raw medical waste, however, due to the coaxial SCC design, the combustion temperature in the SCC varied slightly with time. The temperature has great effect during the formation of pyrolysis gas such as CO. The low air level (40%) in the PCC well controlled the chamber’s temperature. They found that the concentration measured value of the CO represented the best available estimate of environmentally satisfactory operation for the incineration process. Moreover, the destruction efficiency of total CO in the SCC is round 99.95%. Emission concentrations of pollutants in the stack were also measured and met the demand of the China National Incineration Emission Standard.

W. Jangsawang, et. al. [4] made a research dealing with investigation of the effects of primary chamber preheating temperature and batch size of the waste feed on the combustion of medical waste in a two chamber controlled air incinerator of 50 kg/h nominal capacity. Thier primary purpose is to determine qualitatively the functional relationships between the key incinerator performance indicators and the above two parameters so that optimum preheating conditions of a pilot incinerator, which has been in trial use at a hospital, may be defined. They were used three batch sizes, namely: 5, 7.5 and 10 kg, with the primary chamber preheating temperature varied from 500 to 800°C at 100°C intervals for each batch. The secondary chamber temperature control was set at 900°C. Their results showed that increasing the waste charging temperature and the weight of charge tend to accelerate the rate of volatile gas release, causing a ‘‘bottleneck effect’’ in the secondary chamber and, hence, a negative effect on the overall performance of the incinerator, as reflected in the residual unburned CO in the gases leaving the chamber.

Also, they were considered CO measurement as a criterion for good combustion makes it possible to determine the optimum incinerator temperature control settings and operating conditions, as well as to assure continuous, efficient, environmentally satisfactory operation. Moreover they were stated that during normal operation, recording of PCC and SCC temperatures, as well as CO, assures continuously efficient combustion and minimum impact on the environment.

Emissions and consumptions at waste incineration plants are mainly influenced by three parameters: waste composition and content, design and operation of incinerator's furnaces (PCC & SCC), design and operation of air pollution control system (APCS). Emissions of HCl, HF, SO2, NO_X, and heavy metals depend mainly on the structure of the waste and the flue-gas cleaning quality (APCS). CO and VOC emissions are determined primarily by design and operation of incinerator's furnaces (PCC & SCC), and the degree of waste heterogeneity when it reaches the combustion stage. The furnaces design and operation to a large extent also affect NO_X. Dust emissions are very dependent upon flue-gas treatment (APCS) performance. Dioxin and furan (PCDD/PCDF) emissions to air depend on waste structure, furnaces (temperature, residence times and turbulent) and plant operating conditions (reformation and *de-novo* synthesis are possible under certain conditions) and flue-gas cleaning performance (APCS) [5]

From the above literature reviews, it is concluded that the measured value of the CO concentration have been represented the best available estimate of environmentally satisfactory operation for the incineration process. Also, it can be considered CO measurement as a criterion for good combustion makes it possible to determine the optimum incinerator temperature control settings and operating conditions, as well as to assure continuous, efficient, environmentally satisfactory operation. Moreover during normal operation, it must be recorded the temperature of both primary and secondary combustion chambers, as well as CO, to assures continuously efficient combustion and minimum impact on the environment.

INCINERATION PLANT

As mentioned in Ref. [6] this incineration plant is composed from the incineration furnaces or combustion chambers, the wet scrubber air pollution control system (exhaust treatment unit), and the electrical control panel. The capacity of these incineration plants is 100kg/hr. See Fig. 1.

The incineration furnaces is of double combustion chambers, which is fabricated from mild-steel, with refractory lined chambers, and insulated from inside. The first combustion chamber is the primary combustion chamber (PCC), which is known as Incinerating combustion chambers, the second combustion chamber is the secondary combustion chamber (SCC), also known as thermal oxidation chamber. The primary combustion chamber is equipped with charging door, ash removal door, and automatic oil-burner operated by temperature indicating controller (thermostat) which is set at 800±50°C, connected to the electric control panel. Waste is to be fed manually inside the primary combustion chamber through the charging door. Also, the ash is removed manually through ash removal door.

The secondary combustion chamber (thermal oxidation chamber) is equipped with automatic oil-burner operated by temperature indicating controller (thermostat), which is set at 1150±50°C connected to the electric control panel. Minimum 2 second residence time is provided for flue gases in this chamber (according to law 94/1994). Additional combustion air from air blower is provided through a number of internal ports fitted in the side walls of the primary and secondary combustion chambers. This additional combustion air is used to ensure the completeness of incineration and pyrolysis processes in primary combustion chamber, and the completeness of oxidation of pyrolytic off-gases in secondary

combustion chamber. The primary oil-burner is used to ignite the wastes and generate heat, so volatilisation of waste is achieved in primary combustion chamber through supply of air through various ports on all sides of the primary combustion chambers. Therefore, in the incineration process, the waste is thermally decomposed in the primary combustion chamber at a temperature of 800±50°C. The pyrolytic off-gases products (volatile mater) are completely oxidised in the secondary combustion chamber due to "3Ts Rule": sufficient residence time (2seconds), high temperature (1150±50°C.) high mixing turbulence with excess air (oxygen).

The wet-scrubber air pollution control system is associated with this incineration plant. This wet scrubber exhaust treatment unit, consists of a sequential separated unites to ensure the removal of environmental pollutants. It comprises; caustic soda solution tank, venturi wet-scrubber, caustic soda tray tower-scrubber, two liquid separation chambers, tall chimney (stack), and blower (ID fan). This unite is used to clean the contaminated gases emitted from both incinerating combustion chambers (furnaces). The incineration plant has a large chimney, which is enough to prevent the restriction of the flow of flue gases, and ensure natural draught. Also, according to the rules of the "Egyptian Environmental Affairs Agency (EEAA), Ministry of State for Environmental Affairs, Arab Republic of Egypt" The height of the chimney is taller with 3.5meter than any buildings in a circle of 50 meter diameter around the chimney.

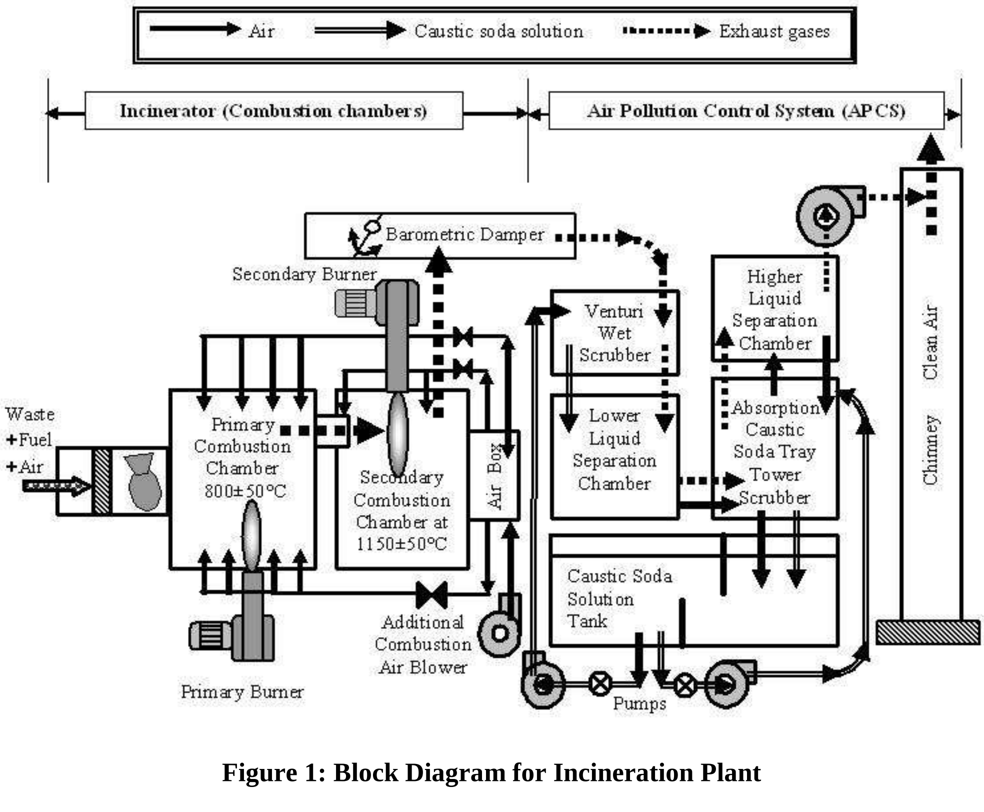

Figure 1: Block Diagram for Incineration Plant

EXPERIMENTAL WORK

Many of hazardous (biomedical) waste incineration plants with various capacities (50, 100, and 250kg/h) were built in different hospitals of Ministry of Health & Population at different Egyptian cities. The design details, technical specifications, manufacturing, installation, and operation of each of these hazardous (biomedical) waste incineration plants had been reviewed, inspected, and checked by the members of the committees of inspection and receipt of Directorate of Health & Population in each city.

The members of these committees were observed and followed up the erection and installation, and investigated all components of incineration plant, before and during incineration process, and during its cooling period. They were weighed the charged quantity of the hazardous waste according to the capacities of each incinerator, and weighed the quantity of the residual ash which was produced at the end of each run. Also, they were recorded the variation of the operating parameters, the volume reduction, effectiveness of destroying the wastes for these incinerators.

The cooperation Egyptian committees for the "Administration of Hazard wastes" was recommended that each new installed incineration plant must be subjected to the investigation of the "Evaluation of Gaseous Emission", to confirm that the operating and performance parameters and gaseous emissions of the incineration plant meet the standard levels of "Egyptian Environmental Affairs Agency" (EEAA). This recommendation must be achieved by the same approved reference laboratories:

- Reference laboratory of Faculty of Science, Ain Shams University, in cooperation with the Egyptian Environmental Affairs Agency, which have been installed by Danish Project for Environmental Monitoring
- Laboratories of Environmental Measurements of branches of the Egyptian Environmental Affairs Agency (EEAA)

Performance and Operating Testing Parameters [7]

There are some parameters must be measured and recorded for these incineration plants to illustrate their performance testing, and to ensure the perfect operation and performance of these incineration plants as designed. These parameters are: feeding rate of waste (according to its capacity), temperature in primary and secondary combustion chambers, temperature of the outer surface of the incinerator body, gaseous emissions rising from the chimney of these incineration plants, quantity and quality of residual ash produced from incineration process, destruction rate, and operation conditions for example, difficulties of operation of incineration plants, and problems and obstacles that face their operators

Evaluation of Gaseous Emission

The "Evaluation of Gaseous Emission" emitted from the chimney during the operation of each new built hazardous waste incineration plant (capacity 50, 100, 250kg/h), were done by approved "Reference Laboratory of Faculty of Science, Ain Shams University", see Table (1&2). These incineration plants were built in; hospital of "Minia city" with a capacity of 100kg/h, hospital of Leper of "Abo-Zaabal city" with a capacity of 50kg/h, Environmental Protection Society at "Al-Eddoa village, Fayoum city" with a capacity of 100kg/h, and hospital of Assuit University with a capacity of 250kg/h.

While, two incineration plants which were built in hospital of "Sinbllaween city' with a capacity of 100kg/h, and hospital of "Talkha city" with a capacity of 100kg/h, were investigated by (EEAA) Branch of Dakhlia Governorate. Also, the same previous mentioned incineration plant of "Minia city" (capacity of 100kg/h) was subjected to the investigation by (EEAA) Branch of Assuit Governorate, see Table (3). A detailed catalogue for each incineration plant was studied by the committee of each laboratory. The technical specifications, design details, and operation of these incineration plants had been reviewed, inspected, and checked by the members of the committee of each laboratory. These committees came to each incineration plant in its site in which incineration plant was built. They weighed a quantity of the hazardous wastes according to the capacity of the incineration plant.

They charged the primary combustion chamber of the incinerator by this quantity of wastes. Then, they started the operation of incineration plant, and began to measure and record the variation of temperatures of both combustion chambers, and the temperature of the outer surface of the incinerator body. Also, the species concentration (from port at the chimney) during its incineration process were measured and recorded. Finally, they weighed the quantity of the residual ash after cooling period. It is worth noting that, these committees investigated the components of incineration plant, before and during the incineration process, and during its cooling period.

Measuring Technique of "Evaluation of Gaseous Emission"[8]

The "Evaluation of the emissions" from the operation of our incineration plant was done by the "Reference Laboratory, Faculty of Science, Ain Shams University, Egypt". The Lab., used a measuring plane depends on examination and analysis of the gaseous combustion products (emission) rising from the chimney of the incinerating plant, to determine the content of the rising vapours (species concentration), volatile metals, and the vapour of the organic compounds, also, comparing this measured values with the standard values issued by the "Egyptian Environmental Affair Agency (EEAA), Ministry of Environment". An automatic sampling device was supported at a port drilled in the latter part of the chimney of the incineration plant, to collect emissions from the chimney, either fly ash, or gaseous emission (neutral or acid gases), or organic compound during the extent of the burning (incinerating) is complete (about one hour), at a time. The calculation of these measurements based on 10% Oxygen.

The variation of the temperatures of both primary and secondary combustion chambers, the temperature of the emission (exhaust gases) from the chimney, and the temperature of the outer surface of incinerator body were measured and recorded, to illustrate the effect of the fluctuation of these temperatures on gaseous emission. Gases of hydrogen chloride, and hydrogen florid, in gaseous emissions emitted from the chimney, were collected in the alkaline solution, and the detection and quantitative evaluation of them, were measured using "Ion-selective electrodes" device.

The detection and quantitative evaluation of the concentration of oxygen, carbon monoxide, carbon dioxide, sulphur dioxide, nitrogen oxides in emission were measured using "Electrochemical Cells". Also, the metallic elements in the gaseous emissions collected in a known volume of nitric acid (5%), as well as collecting solid particles suspended on filters, and melting sediment in nitric acid, and processed it, and measured their content of metallic elements by ""Atomic Absorption Spectrometry" device. Measurements were taken twice and averaged the results.

RESULTS AND DISCUSSIONS OF PERFORMANCE AND OPERATING TESTING

The measured values of "Operating parameters" and the "Evaluation of gaseous emissions" from the operation of some different of previous mentioned hazardous waste incineration plants which were installed in cities of Minia, Abo-Zaable, Fyoum and Assuit with a capacities of (50, 100 and 250kg/h), were done by the laboratories who has been approved by "Egyptian Environmental Affairs Agency" (EEAA).

Operating Parameters

The Reference laboratory of Faculty of Science, Ain Shams University, Egypt, was investigated both the "Operating parameters" and the "Evaluation of gaseous emissions" for these incineration plants.

Table 1: Operating Parameter of Incineration Plants

Measured by Reference Laboratory, Faculty of Science, Ain Shams University, Egypt							
NO.	**Constituents**	**Units**	**Hospitals**				
			Minia [8]	**Gezam [9]**	**Fayom [10]**	**Asuit-1 [11]**	**Asuit-2 [12]**
Incinerator Capacity (kg/hr)		kg/hr	100	50	100	250	250
Charge weight.		Kg	110	45	100	240	220
Ash weight.		Kg	4.5	2.0	4.4	10	9
Rate of destruction		%	96%	95.6%	95.6%	95.8%	96%
Standard Range of Temp of PCC			**800±50°C**				
Temp. of primary comb. chamber		°C	820	830	810	840	830
Standard range of temp of SCC			1150±50°C				
Temp. of secondary comb. chamber		°C	1100	1120	1110	1130	1140
Standard Range of Temp of Outer Surface of Incinerator Body				**= Room Temp + 20°C**			
Temp. of outer surface of incinerator body		°C	45	38	37	46	36
Room temp.		°C	32	25	26	30	25
Temp of exhaust gases rising from chimney		°C	120	115	110	126	130

Table (1) and Fig.(2) showed that, the temperature of primary combustion chambers was varied between 810-840ºC, the temperature of secondary combustion chambers was varied between 1100-1140ºC. Figure (3) showed the temperature of gaseous emission from the chimney was varied between 110-130ºC, and the temperature of the outer surfaces of the incinerator bodies was varied between 37-46ºC, while, the ambient temperature was varies between 25-32ºC.

So, these temperature measuring values ensured that the incinerating plants were operated in proper condition and identical to the design and standard levels issued from "Egyptian Environmental Affair Agency (EEAA)" according to "Law No.4/1994 & Executed Regulations No. 338/1995". The variation of the measured temperatures for these incineration plants may be explained due to the variation of the composition of the mixture of the hazardous waste and the effect of the ambient temperature from site to site.

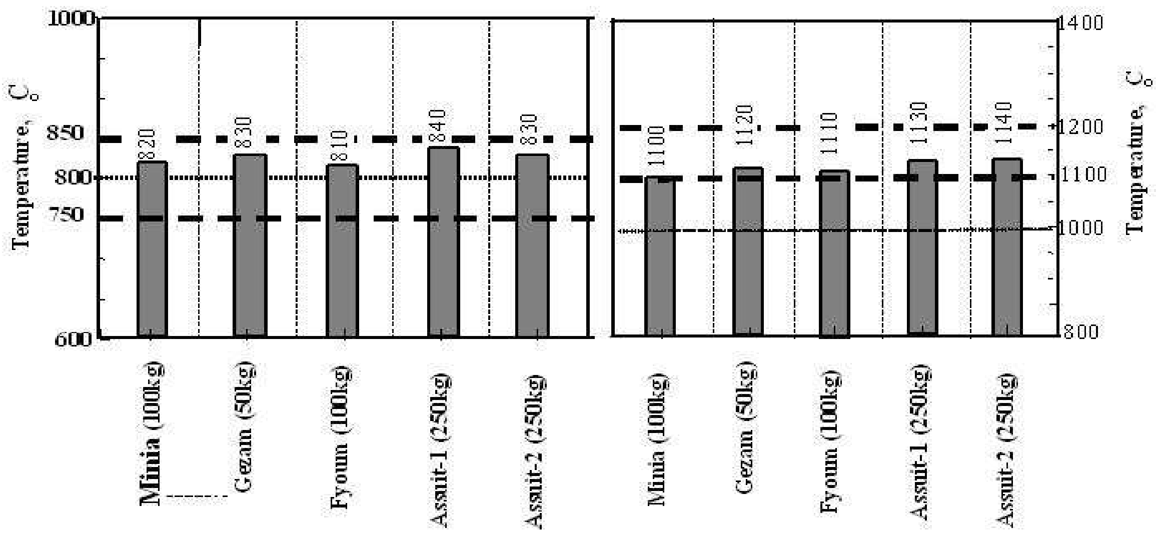

Figure 2: The Higher, Lower and Average Measured Values of the Temperatures of Primary and Secondary Combustion Chambers for Different Incineration Plants

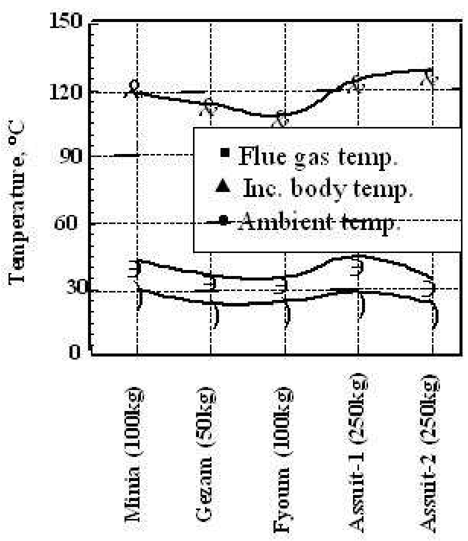

Figure 3: The Average Measured Values of the Temperatures of Exhaust Gases from the Chimney, Outer Surface Body of the Incinerator, and Ambient

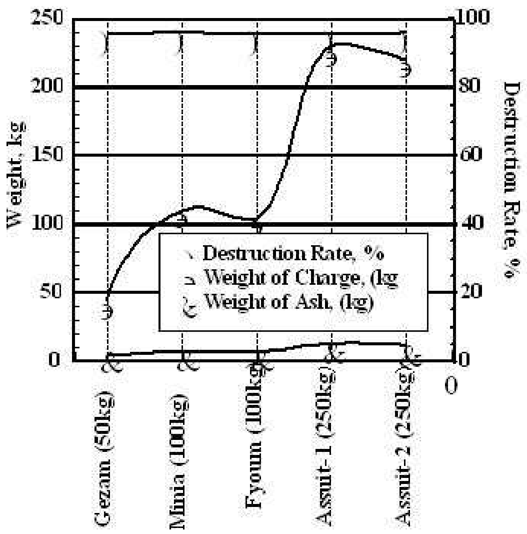

Figure 4: The Weight of Charge, Weight of Ash and the Destruction Rate for the Different Incineration Plants

The primary combustion chambers of these incineration plants were charged with quantities according the capacity of each incinerator, which were varied between 50-250kg/h. Quantity of ash resulted from destruction can be used to indicate destruction efficiency in percentage of reduction in mass of waste. Figure (4) showed that the quantities of the residual ash were varied between 2-10kg (4-5% of feeding waste), corresponding to destruction rate varied between 95-96% according to the incinerator capacity. Destruction rate is a measure of capability in eliminating the infectious waste per hour and it is used to approximate quantity of the waste to be destroyed per cycle and to predict other expenditures

"Evaluation of Gaseous Emissions"

The "Evaluation of Gaseous Emissions" emitted from the chimney of the hazardous waste incineration plants for hospitals, were done by the early mentioned laboratories who have been approved by (EEAA):-

Investigation by "Ref. Lab. of Faculty of Science, Ain Shams University, Egypt"

Hazardous waste incineration plants emit significant quantities of pollutants to the atmosphere. These pollutants include: particulate matter (PM), acid gases (HCl, SO2 and HF), oxides of nitrogen (NOx), carbon monoxide (CO), organics, and metals. The average measured values of solid and gaseous emissions rising from the chimneys of various incineration plants during the incineration (burning) of hazardous waste, for different constituents that affected on the environmental pollution, were shown in Table (2).

Figure (5) showed the average measured values of concentrations of PM, HCl, Organic carbon (OC), CO, SO2, & NOx gaseous emissions rising from the chimneys of the incinerating plants. Particulate matter (PM) is emitted as a result of incomplete combustion of organics (i. e., soot) and by the entrainment of non combustible ash due to the turbulent movement of combustion gases. Uncontrolled particulate emission rates vary widely, depending on the type of incinerator, composition of the waste, and the operating practices employed.

Controlled air incinerators have the lowest turbulence and, consequently, the lowest PM emissions. Most of this particulate is captured by the facility's APCS and are not emitted to the atmosphere [13]. It was important to note that the

concentrations of fly ash within first half hour of burning is higher than in the second half time, this due to the beginning of the burning (incineration) process of wastes.

The average measured value of the concentration of PM was varied from 6.9 to 9.05 mg/m^3, see Fig.(5-A). The average measured values of the concentrations of organic carbon in gaseous emissions, rising from the chimneys of the incineration plants during the incineration (burning) of hazardous waste, were varied from 1.4 to 7.4 mg/m^3.

Many wastes contain chlorinated organic compounds or chlorides. Hydrochloric acid (HCl) is resulted from combustion of hydrogen and chlorine contained in waste. Most of the chlorides come from PVC incineration process, the organic component of these compounds is destroyed and the chlorine is converted to HCl. Part of the HCl may react further to metal chlorides on inorganic compounds which are also contained in the waste. HCl is highly soluble in water and has an acidic impact on (APCS) of incineration plant and results in damage of its walls. Measured HCl can be used to indicate an amount of chlorine in the waste and possibility of dioxin formation in incineration process [5,13]. The average measured value of concentration of HCl from operating & performance testing of the prototype of incineration plants were varied from (5.6 to 8.3mg/m^3) which does not exceed the standard value (10.0 mg/m^3) issued from the (EEAA), see Fig.(5-A).

Also, from the same Table (2), the average measured values of the concentrations of Hydrofluoric acid (gas) in gaseous emissions, rising from the chimneys of the incineration plants during the incineration (burning) of hazardous waste, were varied from 0.2 to 0.6 mg/m^3, which were less than that of standard values (2.0 mg/m3) issued from the (EEAA).

Table 2: Evaluation of the Emissions from the Operation of Hazard Waste Incineration Plants for Some Hospitals

Measured by Reference Laboratory, Faculty of Science, Ain Shams University							
NO	**Constituents**	***Standard (mg/m^3)**	**Hospitals**				
			Minia [8]	**Gezam, Abo-Zaabl [9]**	**Fyuom Env., Socity [10]**	**Asuit-1 Univ. [11]**	**Asuit-2 Univ. [12]**
Incinerator Capacity (kg/hr)		kg/h	100	50	100	250	250
1	Particulate Matter	10	8.7	8.7	9.05	7.20	6.9
2	Organic Carbon	10	1.4	3.7	5.70	5.80	7.4
3	Hydrochloric Acid (Hydrochloric gas)	10	8.3	5.6	6.00	7.20	6.5
4	Hydrofluoric Acid (Hydrofluoric gas)	2.0	0.3	0.5	0.60	0.20	0.2
5	Sulphuric Dioxide	50	25.06	8.5	20.45	24.5	7.9
6	Nitrogen Oxides	200	88.1	84.5	53.10	45.5	53
7	Carbon Monoxide	100	80.2	92.5	86.40	28.0	43
8	Cadmium & its Components	0.1	0.001	0.006	0.005	0.004	0.003
9	Thallium & its Components	0.1	0.001	0.002	0.005	0.004	0.005
10	Mercury & its Components	0.1	0.001	0.001	0.002	0.003	0.002
11	Zurich & its Components	0.1	0.041	0.002	0.004	0.004	0.003
12	Lead & its Components	0.1	0.081	0.016	0.017	0.018	0.015
13	Chrome & its Components	0.1	0.082	0.026	0.027	0.029	0.025
14	Cobalt & its Components	0.1	0.044	0.013	0.023	0.025	0.018
15	Cupper & its Components	0.1	0.085	0.021	0.025	0.023	0.022
16	Manganese & its Components	0.1	0.044	0.041	0.047	0.043	0.045
17	Nickel & its Components	0.1	0.041	0.032	0.035	0.038	0.033
18	Vanadium & its Components	0.1	0.032	Non	Non	Non	Non
19	Tin & its Components	0.1	0.024	0.01	0.018	0.020	0.019

20	Metals & its Components	5.0	0.16	0.170	0.208	0.18	0.19
21	Dioxin & Furan (Nanogm/m^3)	0.1	0.08	—	—	—	—
The calculation based on 10% Oxygen							
*Egyptian Environmental Affairs Agency, "Law No.4/1994 & Executed Regulations No. 338/1995".							

Carbon monoxide (CO) is an odourless toxic gas. CO in the flue-gas of incineration plants is the product of the incomplete combustion of carbon based compounds. CO is produced when there is insufficient oxygen locally and/or insufficiently high temperature of combustion to carry out full oxidation to carbon dioxide. In particular, this can occur if spontaneously evaporating or rapid-burning substances are present, or when combustion gas mixing with the supplied oxygen is poor.

The CO level can be used to indicate the efficiency of the incineration process. CO is a measure of quality of combustion. If the CO emissions are very low then the gas burn out quality is very high [5,13]. The average measured value of the concentration of carbon monoxide were varied from (28.0 to 92.5 mg/m^3) which were less than that of standard values (100.0 mg/m^3) issued from the (EEAA), see Fig.(5-B).

If the waste contains sulphur compounds, mainly sulphuric dioxide (SO2) will be created during the incineration of the waste. SO2 gives rise to acidification. Under appropriate reaction conditions, SO3 can also be created [5,13]. The average measured value of the concentration of SO2, were varied from (7.9 to 25.06 mg/m^3) which were less than that of standard values (50.0 mg/m^3) issued from the (EEAA), see Fig.(5-C).

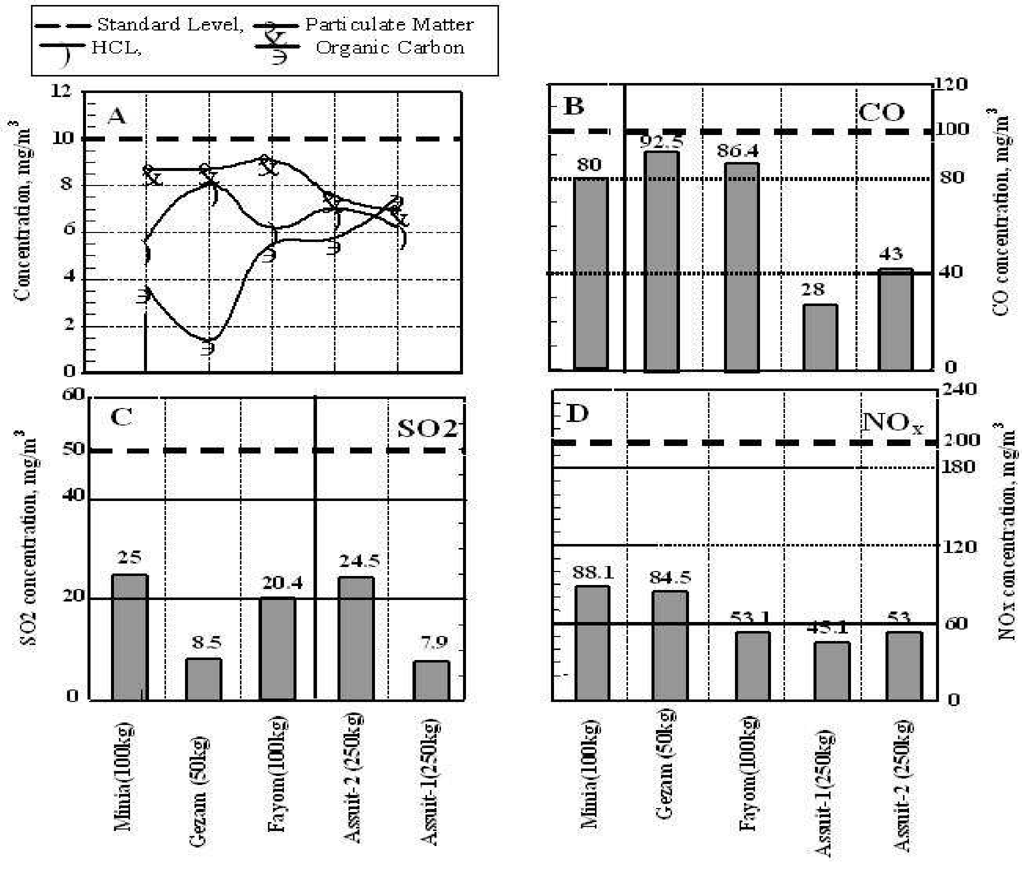

Figure 5: The Standard levels and the Variation of Measured Values of PM, HCl, OC, CO, SO2, & NOx Concentration from Various Hazardous Waste Incineration Plants for Hospitals

Nitrogen oxides (NOx) represent a mixture of mainly nitric oxide (NO) and nitrogen dioxide (NO_2). They are formed during combustion by: (1) oxidation of nitrogen chemically bound in the waste (so-called fuel NO_X), and (2) reaction between molecular nitrogen and oxygen in the combustion air (thermal NO_X). Production of thermal NOX generally becomes more significant at temperatures above 1000°C. The formation of NOx is dependent on the quantity of fuel-bound nitrogen compounds, flame temperature, and air/fuel ratio The proportion of NO/NO_2 in the total NOx stack emissions is usually approx. 95% NO and 5% NO_2. [5,13]. In addition NOx is a secondary source of air pollution such that, as combined with hydrocarbon an ozone in sunlight it may cause smog [7]. The average measured values of concentrations of NOx were varied from (45.5 to 88.1 mg/m^3) which were less than that of standard values (200.0 mg/m^3) issued from the (EEAA), see Fig.(5-D).

While, the concentrations of phosphorus oxides gases were not evidenced by the presence of phosphorus oxides in gaseous emissions rising from the chimneys of the incineration plants during the burning (incineration) process. Also, the average measured values of concentrations of metallic elements levels including lead, cadmium & its components, thallium & its components, mercury & its components, Zurich & its components, lead & its components, chrome & its components, cobalt & its components, cupper & its components, manganese & its components, nickel & its components, vanadium & its components, tin & its components, and metals & its components, in gaseous emissions rising from the chimneys of the incinerating plants, were less than the standard values of the (EEAA).

It is worth to note that, because the measurements of both dioxin and furan were very expensive, the two committees responsible for "Hazard material & Wastes" had satisfied to measure them for the incineration plant which was manufactured primarily, and the following next incineration plants would be measured their "Evaluation of gaseous emission" without the measuring of both dioxin and furan. So, the average measurement values of concentrations of carcinogenic Dioxin & Furan, in gaseous emissions rising from the chimney of the incineration plant of hospital of Minia city were less than the standard values of the (EEAA), this ensure the proper design and operation of our incineration plant .This achievement is due to the "3Ts Rule" in both two combustion chambers of incinerator: high combustion Temperature, adequate combustion Time (usually 2 seconds), and high combustion mixing Turbulence to distribute heat evenly and ensure complete destruction. Moreover, the so-called "fast-quenching" for exhaust gases in "wet-scrubber air pollution control system", cool the gases quickly and prevent the reformation of both dioxin and furan compounds.

Therefore, our incineration plants have been achieved the levels less than that required for standards and guidelines for the "Evaluation of gaseous emissions" issued from "Egyptian Environmental Affair Agency (EEAA)" according to "Law No.4/1994 & Executed Regulations No. 338/1995". Hence, after these proper results of these evaluations for our hazardous waste incineration plants for hospitals, the Egyptian committees for "Hazard material & Wastes", were confirmed that our incineration plant is well designed and comply with the standard and guidelines rules of "Egyptian Environmental Affair Agency (EEAA)". So, it is worth to state that, the Egyptian committees for "Hazard material & Wastes" has been approved on the technology that is used in the design of our incineration plant.

Investigation by "Lab. of Environmental Measurements", Branch of (EEAA)

Another three of our hazardous waste incineration plants, were subjected to the investigation of the "Evaluation of Gaseous Emission" by "Laboratories of Environmental Measurements" of branches of the "Egyptian Environmental Affairs Agency", (EEAA). "Laboratory of Environmental Measurements" branch of "Central Administration of East Delta" (Mansora) affiliated to the (EEAA) was measured gaseous emission from the operation of two of our hazardous

(biomedical) waste incineration plants which were built in "Hospital of Sinbellaween city", and "Hospital of Talkha city", Dakhlia Governorate, Egypt.

Also, "Laboratory of Environmental Measurements" branch of "Central Administration of Middle Egypt" (Assuit) affiliated to the (EEAA), was measured gaseous emission from the operation of one of our hazardous waste incineration plant which was built in "Hospital of Minia city", Minia Governorate, Egypt. These laboratories of "Egyptian Environmental Affairs Agency (EEAA)" were measured the concentration of three compounds only of pollutant gaseous emissions: "carbon monoxide, sulphur dioxide, and nitrogen oxides". As these three pollutant gases are sufficient to indicate the proper operation and performance of the incinerating process. Table (3) showed that the measured values of these three species concentrations. So, the average measured values of the concentrations of carbon monoxide in gaseous emissions emitting from the chimney of our three incineration plants were varied from (50, 76.5 to 83.6 mg/m^3), which were less than the standard values (100 mg/m^3) issued from (EEAA). And the average measured values of the concentrations of sulphuric dioxide in gaseous emissions emitting from the chimney of our three incineration plants were varied from (6, 26 to 35.5 mg/m^3), which were less than the standard values (50 mg/m^3) issued from (EEAA). While, the average measured values of the concentrations of nitrogen oxides in gaseous emissions emitting from the chimney of our three incineration plants were varied from (52, 63.8 to 112.7 mg/m^3), which were less than the standard values (200 mg/m^3)issued from (EEAA). Therefore, the results of the "Evaluation of Gaseous Emissions", which were done by "Branches of Laboratory of Environmental Measurements" affiliated to (EEAA) have been confirmed that the levels of the measured values of the concentrations of the emitted pollutant gases from the chimney of our hazardous waste incineration plants were less than that required for standards and guidelines issued from "Egyptian Environmental Affair Agency (EEAA)" according to "Law No.4/1994 & Executed Regulations No. 338/1995".

Table 3: Species Concentration Emitted from the Operation of Hazard Wastes Incineration Plants for Hospitals, Measured by the Laboratory of Egyptian Environmental Affairs Agency (EEAA)

No		Standard Law 4/1994	Sinbllaween (1) Hospital [14]	Talkha (1) Hospital [15]	Minia (2) Hospital [16]
		(mg/m^3)	1/9/2008	4/3/2009	
1	Carbon Monoxide	100	83.6	76.5	50
2	Sulphuric Dioxide	50	35.5	6.0	26
3	Nitrogen Oxides	200	112.7	63.8	52
(1) Central Administration of Delta East (Mansora)					
(2) Central Administration of Middle Egypt (Assuit)					

CONCLUSIONS

From results of operation and performance testing of different of the hazardous waste incineration plants for hospitals, it was found that the prototype incineration plants are satisfied for all specified criteria such as operating parameters, gaseous emissions (air pollution) and ash do not exceed standard levels issued from (EEAA). In conclusions the prototype incineration plants can be constructed to use for destroying effectively of hazardous (biomedical) waste from hospitals and is not affected to environmental. Also, it is worth to note the carbon monoxide is gas emitted from incomplete combustion and is used to indicate the efficiency of incineration process.

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